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Relationship Between Magnitude of Resection, Complication, and Prosthetic Survival After Prosthetic Knee Reconstructions for Distal Femoral Tumors

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Background and Objectives: Limb-sparing surgery has become the preferred surgical treatment of malignant bone tumors. The objective of this study was to evaluate factors that influence the morbidity and outcome of prosthetic knee replacement after resection of malignant tumors of the distal femur.
Methods: Eighty-two patients who had a resection of malignant tumor of the distal femur and implantation of a segmental knee prosthesis (minimum follow-up, 2 years) were retrospectively reviewed.
Results: Twenty-nine patients (35%) underwent 32 prosthetic revisions, 6 from perioperative wound complications, 13 from aseptic loosening, and 13 from other complications. The 3-, 5-, and 10-year Kaplan-Meier prosthetic survival rates were 82%, 71%, and 50%, respectively. On univariate analysis, patients who had more than 40% resection of the distal femur ($P = 0.010$) and those who had all their vasti muscles resected ($P = 0.011$) had significantly worse prosthetic survivals than the others. On multivariate analysis, resection of more than 40% of the distal femur was a significant negative prognostic factor for prosthetic survival ($P = 0.017$). Aseptic loosening was the primary cause of late prosthetic failure. Differences in the magnitude of resection influenced prosthetic survivorship more than prosthetic design.
Conclusions: In the distal femoral endoprosthetic replacement, higher short- and long-term complications were found after extensive resections. Aseptic loosening was the primary cause of prosthetic failure.
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KEY WORDS: **malignant bone tumor; distal femur; limb-sparing surgery; endoprosthesis; complication; aseptic loosening**

INTRODUCTION

Limb-sparing surgery has become the preferred surgical treatment of malignant tumors of the distal femur [1–9]. Functional success has not matched the oncologic success of these procedure. An elusive goal is a durable reconstruction that retains a mobile knee. Prosthetic reconstruction offers the advantages of maintaining knee motion and immediately restoring function, an especially important outcome for patients with a limited life span [10]. However, short- and long-term complications plague this approach [11,12]. Factors that influence the morbidity and outcome of knee replacement surgery are

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not well documented and should be understood in order to reduce complications from these procedures. We report the analysis of the largest American series studied with this purpose in mind.

MATERIALS AND METHODS

Patients

Between 1979 and 1995, we treated 111 patients with malignant tumors of the distal femur by excision of the lesion and reconstruction with a segmental distal femoral endoprosthesis. Of the 111 patients, 24 patients died of metastatic disease within 2 years and 5 patients were lost during follow-up. Of the 24 patients who died within 2 years, 6 patients (25%) developed perioperative wound complications and 2 patients (osteosarcoma 1, cancer metastasis 1) developed local recurrences, and 4 patients underwent complete prosthetic exchange (including 2 amputations).

The subjects of this study were the remaining 82 patients who had implantation of a large segmental prosthesis and had a minimum postoperative follow-up period of 2 years. The mean and median follow-up periods were 5.6 and 4.8 years, respectively (range, 2–17 years). There were 43 males and 39 females. The ages of the patients at operation ranged from 12 to 71 years (mean, 27 years). The tumor diagnosis was osteosarcoma in 59, chondrosarcoma in 9, Ewing sarcoma in 5, malignant fibrous histiocytoma in 5, and 1 each of malignant giant-cell tumor, liposarcoma, spindle-cell sarcoma, and metastatic renal-cell carcinoma. Surgical stages that were assigned according to the Musculoskeletal Tumor Society Classification [13] were stage IIB in 70 patients, stage IB in 6 patients, and stage III in 6 patients. Sixty-six patients received pre- and postoperative chemotherapy with regimens used in the institution at that time [14,15]. Sixteen patients (chondrosarcoma 8, osteosarcoma 4, others 4) did not receive chemotherapy. No patient had preoperative radiation therapy.

Operative Treatment

The operation was performed through a medial (54 patients) or lateral (28 patients) parapatellar approach that included an elliptical resection of the biopsy site en bloc with the tumor. The tumor excision was carried out following oncological principles with a wide resection margin. Prior to the availability of and reimbursement for magnetic resonance imaging (MRI), 5-cm bone margin, extrafascial dissection, and extra-articular excisions were done routinely [16]. Subsequently margins were narrowed, taking 2 cm of extra bone and performing subfascial dissection with more than a 2-cm soft-tissue margin from the biopsy track or penetrating areas of tumor. Joint resection was limited to those cases where there was an effusion after chemotherapy, ligament involvement by MRI, or fracture [9]. Vascular dissection was performed in the adventitia at the popliteal vessels. Margins were commonly 1–2 mm in the area. Neither reactive tissue nor tumor were ever cited to be present at this margin.

The excision was entirely extra-articular in 49 patients and intra-articular in 33 patients. The length of distal femur resected ranged from 11 to 33 cm (mean, 22.0 cm). The percentage of bone resected that was calculated from measurements of anteroposterior radiographs ranged from 21 to 67% (mean, 41.4%). Resection of all vasti (medialis, lateralis, and intermedius) muscles was performed for 28 patients. Fourteen patients had muscle transfers to facilitate wound closure (rotation flaps of gastrocnemius muscles 7, free latissimus dorsi flap 5, anterior transfer of biceps muscles 2) [17–19]. In 18 patients, an attempt was made to provide active extension by anterior transfer of the sartorius muscle to the patella or the remaining patellar ligament.

Prostheses

Fifty-one patients received Lane-Burstein knee prostheses (Biomet, Warsaw, IN) and 31 patients had Finn Knee prostheses (Biomet). The mean follow-up period was 7 years (range, 2–17 years) for Lane-Burstein knee prostheses and 3.2 years (range, 2–7 years) for Finn Knee prostheses. The basic design of the Lane-Burstein prosthesis has been reported previously [20]. The joint design is a semiconstrained hinge that permits 130 of flexion, 3.5 of hyperextension, and minimal rotational and varus/valgus motions. Hyperextension enhances knee stability in the stance phase of gait even in the absence of quadriceps function. The Finn Knee prosthesis has a rotating-hinge mechanism that permits movement in three directions (flexion-extension, rotation, and distraction) between femoral and tibial components [21]. Since it has a weight bearing rotating tibial articulation, weight bearing is shared throughout the prosthesis and not borne by the axle alone.

Femoral components were press-fit with porous ingrowth surfaces in 55 patients and cemented in 27 patients. Tibial components were press-fit in 26 patients and cemented in 56 patients. Young patients with primary tumors received press-fit components if a tight press-fit could be obtained intraoperatively. The prostheses have similar femoral stem design and have extramedullary porous coating adjacent to the femoral osteotomy site to enhance bone bridging between host bone and the prosthesis. Extracortical bone grafting was performed using local bone graft harvested from the epiphyseal bone of the autogenous noncancerous tibial plateau plus intramedullary reamings.

TABLE I. Prosthetic Knee Reconstruction: Complications

Complications	Number	Prosthesis exchange[a]
Wound complications	18	6 (2)
Aseptic loosening	18	13 (2)
Fracture	9	2
Late infection	5	4 (1)
Polyethylene component breakage	4	4
Extension contracture	2	
Femoral component breakage	1	1
Injury communicated with prosthesis	1	
Patella subluxation	1	
Loose body	1	
Local recurrence	2	2 (2)
Total	62	32 (7)

[a]The number of amputations in parentheses.

Assessment of Results

Failure of reconstruction was defined as any cause that required replacement of the components of the prosthesis. Survival curves were determined using the Kaplan-Meier method [22]. Differences in survival between groups were determined by the log-rank test. Multivariate analysis was performed using the Cox proportional hazards model [23]. To arrive at a parsimonious multivariate model, covariates were selected with a stepwise regression model using backward elimination. Student *t*-test and chi-square test were used to compare continuous and categorical variables in the two groups. *P* values were based on two-tailed tests and at <0.05 were considered significant.

RESULTS

At the time of last follow-up, 65 patients were free of disease, 9 patients were alive with metastatic disease, and 8 patients had died of disease. The 5-year survival of the original 111 patients was 73%.

Complications

Eighteen of 82 patients (22%) developed perioperative wound complications (Table I). Six patients underwent complete prosthetic exchange due to skin necrosis and/or infection. The development of skin necrosis and/or infection correlated to the extent of the quadriceps muscle resection. Of the 54 patients who retained more than two heads of the quadriceps muscles (keeping at least one of the vasti), 6 patients (11.1%) developed skin necrosis and/or infection, while 10 out of the 28 patients (35.7%) who had all of the vasti removed developed it ($P = 0.016$). Chemotherapy, type of surgical approach to the distal femur (medial vs. lateral), type of knee joint resection (intra- vs. extra-articular resection), percentage of the distal femur resected, and prosthetic design (Lane-Burstein vs. Finn Knee) did not significantly influence the development of perioperative wound complications.

Fig. 1. Roentgenogram taken 5 years after implantation of Lane-Burstein knee prosthesis showing femoral stem loosening.

Eighteen patients (22%) developed aseptic loosening of the femoral component at an average of 4.2 years (range, 1–11 years) (Fig. 1). Revision of the prosthesis was performed in 13 patients with progressive pain or radiographic bone loss. Of the 51 patients who had a Lane-Burstein knee prosthesis, 16 patients (31.4%) developed aseptic loosening, while 2 out of 31 patients (6.5%) who received a Finn Knee prosthesis developed loosening ($P = 0.012$). Eleven of 28 patients (39.3%)

who had had all of the vasti removed and 7 of 54 patients (13.0%) who retained at least one of the vastus muscles developed aseptic loosening ($P = 0.011$). Age, sex, chemotherapy, surgical approach, type of knee joint resection, percentage of distal femur resected, or methods of femoral stem fixation did not significantly correlate with the development of aseptic loosening.

Nine patients (11%) developed fractures around the prosthesis. Three femoral fractures occurred in patients who had resection of more than 40% of the distal femur. Four patients who had an extra-articular resection with a coronal osteotomy of the patella sustained a patellar fracture. Two tibial fractures developed at the tips of the tibial stem.

Late infections occurred in five osteosarcoma patients who received adjuvant chemotherapy. Three cases were managed successfully with revision of the infected prosthesis and implantation of an antibiotic-permeated methylmethacrylate spacer followed by a staged reimplantation of another prosthesis. One patient underwent above-knee amputation because of recurrent symptomatic infections. A soft-tissue abscess that did not involve the prosthesis was treated successfully with irrigation and debridement.

Failure of the polyethylene components occurred in four patients (Lane-Burstein prosthesis 2, Finn Knee prosthesis 2). These broken components were replaced without replacement of tibial or femoral stems. Two patients with osteosarcoma developed local recurrences. They had above-knee amputation.

Other complications occurred sporadically. Two patients with limited knee flexion underwent surgical lysis of adhesions surrounding the prosthesis and medial and lateral releases of the quadriceps muscles. In each case, prolonged immobilization needed to protect tenuous wound healing during chemotherapy contributed to the ankylosis. Breakage of the femoral component occurred in Lane-Burstein knee prosthesis in one patient. An accidental penetrating injury that communicated with the prosthesis was managed successfully with debridement and gastrocnemius muscle flap coverage.

Prosthesis Survival

Thirty-two revisions were performed in 29 patients, 6 from perioperative wound complications, 13 from aseptic loosening, and 13 from other complications. The 3-, 5-, and 10-year prosthetic survival rates were 82%, 71%, and 50%, respectively (Fig. 2). By univariate analysis, patients who had resection of more than 40% of the distal femur ($P = 0.010$; Fig. 3) and those with total or subtotal resection of the quadriceps muscles ($P = 0.011$; Fig. 4) had significantly worse prosthetic survivals than the others. There were no statistically significant differences in the prosthetic survivals with respect to age, sex, diagnosis, chemotherapy, surgical approach, type of knee joint resection, type of prosthesis, or method of femoral stem fixation (Table II). Overall prosthetic survival of Finn Knees was 82% at 5 years, and survival of Lane-Burstein knees was 64% at 5 years (Fig. 5), but the difference was not statistically significant. On multivariate analysis, resection of more than 40% of the distal femur was a significant negative prognostic factor for prosthetic survival ($P = 0.017$). Limb preservation was achieved in 94% at 3 years and 92% at 5- and 10-years (Fig. 6).

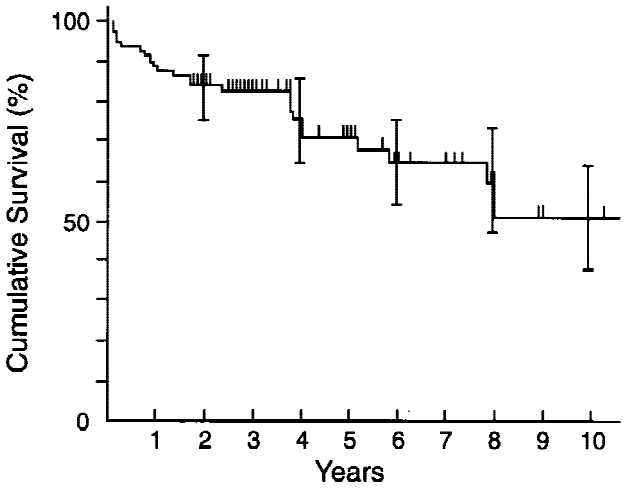

Fig. 2. Prosthetic survival curve of the 82 patients. The I-bars represent 95% confidence intervals.

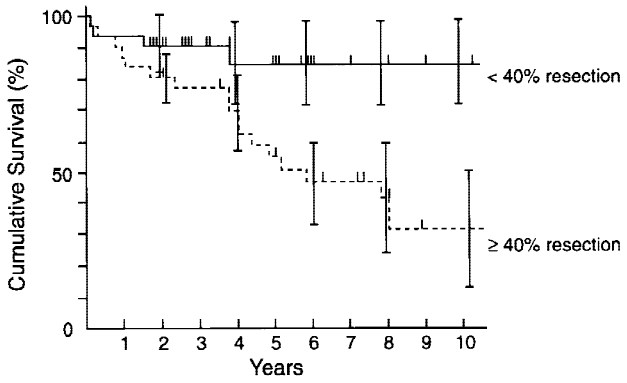

Fig. 3. Kaplan-Meier curves showing the prosthetic survivals according to the extent of the bone resected in the distal femur. Patients who had resection of more than 40% of the distal femur had significantly worse prosthetic survivals ($P = 0.010$). The I-bars represent 95% confidence intervals.

DISCUSSION

Limb-sparing surgery for malignant bone tumors must be successful in two different respects, oncologic cure and reconstructive durability [24]. The 5-year overall survival of the original populations of this study (73%) and local recurrence rate of 3.6% compare favorably with

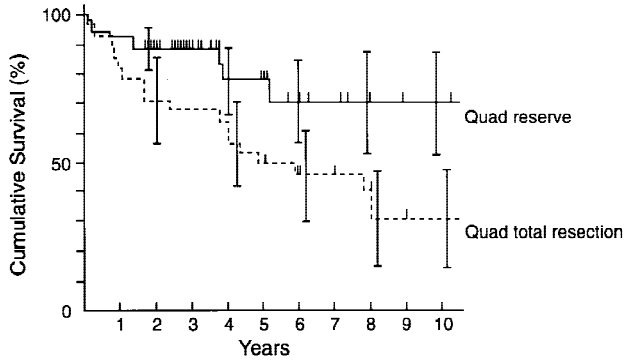

Fig. 4. Kaplan-Meier curves showing the prosthetic survivals according to the extent of the quadriceps muscles excision. Patients who had a total excision of the muscles had significantly worse prosthetic survivals ($P = 0.011$). The I-bars represent 95% confidence intervals.

TABLE II. Prosthetic Knee Reconstructions: Analysis of Factors Predicting Prosthetic Survivals

Factors	Number of patients	5-year survival	Univariate *P* value
Sex			
Male	43	45	0.081
Female	39	76	
Age (year)			
<20	37	58	0.104
⩾20	45	75	
Diagnosis			
Osteosarcoma	59	65	0.832
Others	23	73	
Chemotherapy			
+	66	62	0.127
–	16	81	
Approach			
Medial	54	69	0.213
Lateral	28	72	
Knee joint resection			
Extra-articular	49	59	0.117
Intra-articular	33	80	
Femur resection			
⩾40%[a]	40	55	0.010
<40%	42	84	
Quadriceps resection			
(Sub)total	28	50	0.011
Others	54	78	
Prosthesis			
Lane-Burstein	51	64	0.452
Finn Knee	31	82	
Femoral stem fixation			
Press-fit	55	72	0.903
Cement	27	63	

[a]Selection into Cox model (*P*) is 0.017; coefficient is 1.3; relative risk is 3.7; 95% confidence interval is 1.3–11.1.

the oncologic results of other multi-institutional studies [25,26]. The longevity of the implants was of concern, as prosthetic survivals of 71% at 5 years and 50% at 10 years were noted.

Skin necrosis and/or infection was the most serious

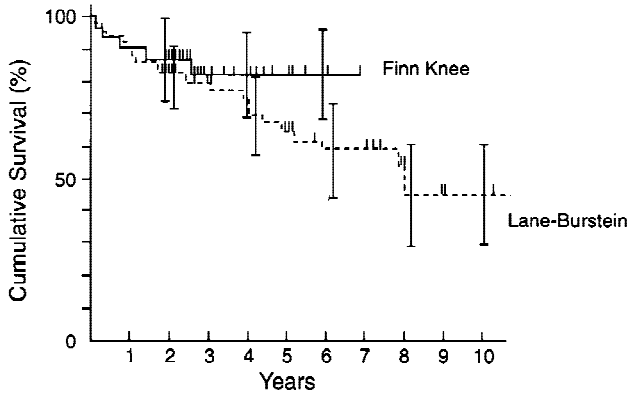

Fig. 5. Kaplan-Meier curves showing the prosthetic survivals according to the design of prosthesis. The I-bars represent 95% confidence intervals.

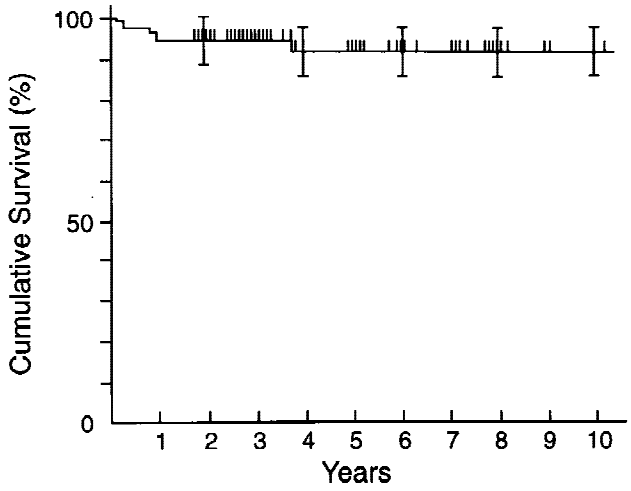

Fig. 6. Limb salvage of the 82 patients. The I-bars represent 95% confidence intervals.

perioperative complication, which necessitated complete prosthetic exchange [27]. We found a higher risk of skin necrosis and/or infection when most of the quadriceps muscles had been excised. Transection of the perforating arteries, poor remaining skin vascularity, and poor muscle coverage of the metallic prosthesis probably contributed to the wound-healing problems. Every effort should be made to cover the prosthesis with vascularized tissue deep to the skin. The use of muscle rotation flaps or vascularized free-tissue transfers should be considered when much of the quadriceps muscles has been excised. When preoperative chemotherapy was effective, we narrowed our margins and dissected deep to fascia. This has reduced the complication rates. More comparative studies of radiographic findings and macroscopic and microscopic examinations of tumor extension are necessary to evaluate critically this surgical philosophy.

The most common cause of prosthetic failure with long-term follow-up was aseptic loosening. Unwin et al.

[28] reported that the aseptic loosening was the primary cause of failure of the Stanmore prosthesis. Concentration of mechanical stresses at the bone implant interface may be responsible for the high incidence of aseptic loosening of hinged knee joint prostheses. The rotating-hinge design is intended to disperse stresses throughout the components and reduce the stresses on the bone implant interface. In this study, the rotating-hinge Finn Knee prosthesis had significantly less aseptic loosening compared to the more constrained, sloppy-hinge Lane-Burstein knee prosthesis. Choong et al. [29] reported only one aseptic loosening after 32 Kinematic rotating-hinge knee replacements with a median follow-up of 3.5 years. Since aseptic loosening increases with the duration of prosthetic implantation, studies with short follow-up may underestimate this complication. More studies with long follow-up are necessary to confirm the usefulness of modern rotating-hinge knee prostheses in decreasing the incidence of aseptic loosening [9].

Univariate analyses of this study showed that the percentage of bone resected in the distal femur and the extent of quadriceps muscle resection were related to the risk of prosthetic failure. Multivariate analysis showed that resection of more than 40% of the distal femur was the only independent adverse prognostic factor for prosthetic survival. The influence of the extent of bone and muscle resections on the development of aseptic loosening or stem breakage of megaprosthesis has been reported [7,9,28]. Capanna et al. [7] found that breakage of the stem of the Kotz prosthesis was associated with greater excision of quadriceps muscles [7]. Increased torque production out of the line of prosthesis and/or impairment of quadriceps contraction may contribute to these complications. Changes in biomechanical stresses after extensive resections of bone and adjacent muscles probably are important factors that determine long-term survival of these implants [30].

Distal femoral endoprosthetic replacement is a good reconstructive option following resection of malignant tumors of the distal femur. Higher short- and long-term complications were found after extensive resections. Aseptic loosening was the primary cause of prosthetic failure. It will be worthwhile to study the changes in biomechanical stresses following extensive resections of the distal femur and quadriceps muscles to help understand the factors contributing to failure of megaprostheses of the distal femur.

REFERENCES

1. Bradish CF, Kemp HBS, Scales JT, et al.: Distal femoral replacement by custom-made prostheses. J Bone Joint Surg [Br] 1987;69B:276–284.
2. Sim FH, Beauchamp CP, Chao EYS: Reconstruction of musculoskeletal defects about the knee for tumor. Clin Orthop 1987; 221:188–201.
3. Roberts P, Chan D, Grimer RJ, et al.: Prosthetic replacement of the distal femur for primary bone tumours. J Bone Joint Surg [Br] 1991;73B:762–769.
4. Ward WG, Eckardt JJ, Johnston-Jones KS, et al.: Five to ten year results of custom endoprosthetic replacement for tumors of the distal femur. In Brown KLB (ed): ''Complications of Limb Salvage, Prevention, Management and Outcome.'' Montreal: ISOLS, 1991:483–491.
5. Shih LY, Sim FH, Pritchard DJ, et al.: Segmental total knee arthroplasty after distal femoral resection for tumor. Clin Orthop 1993;292:269–281.
6. Unwin PS, Cobb JP, Walker PS: Distal femoral arthroplasty using custom-made prostheses. J Arthroplasty 1993;8:259–268.
7. Capanna R, Morris HG, Campanacci D, et al.: Modular uncemented prosthetic reconstruction after resection of tumours of the distal femur. J Bone Joint Surg [Br] 1994;76B:178–186.
8. Malawer MM, Chou LB: Prosthetic survival and clinical results with use of large-segment replacements in the treatment of high-grade bone sarcomas. J Bone Joint Surg [Am] 1995;77A:1154–1165.
9. Kawai A, Muschler GF, Lane JM, et al.: Prosthetic knee replacement after resection of a malignant tumor of the distal part of the femur. J Bone Joint Surg [Am] 1998;80A:636–647.
10. Kneisl JS, Finn HA, Simon MA: Mobile knee reconstructions after resection of malignant tumors of the distal femur. Orthop Clin N Am 1991;22:105–119.
11. Capanna R, Ruggeri P, Decristofaro R, et al.: Complications, their treatment and outcome in 257 cementless megaprostheses. In Brown KLB (ed): ''Complications of Limb Salvage, Prevention, Management and Outcome.'' Montreal: ISOLS, 1991:147–150.
12. Horowitz SM, Glasser DB, Lane JM, et al.: Prosthetic and extremity survivorship after limb salvage for sarcoma. Clin Orthop 1993;293:280–286.
13. Enneking WF, Spanier SS, Goodman MA: A system for the surgical staging of musculoskeletal sarcoma. Clin Orthop 1980;153: 106–120.
14. Meyers PA, Heller G, Healey J, et al.: Chemotherapy for nonmetastatic osteogenic sarcoma: The Memorial Sloan-Kettering Experience. J Clin Oncol 1992;10:5–15.
15. Terek RM, Brien EW, Marcove RC, et al.: Treatment of femoral Ewing's sarcoma. Cancer 1996;78:70–78.
16. Muschler GF, Ihara K, Lane JM, et al.: A custom distal femoral prosthesis for reconstruction of large defects following wide excision for sarcoma. Orthopedics 1995;18:527–538.
17. Missenard G, Tomeno B, Langlais F, et al.: Total knee prosthesis after upper tibia resection for tumors. In Yamamuro T (ed): ''New Developments for Limb Salvage in Musculoskeletal Tumors.'' Tokyo: Springer Verlag, 1989: 591–604.
18. Horowitz SM, Lane JM, Healey JH: Soft-tissue management with prosthetic replacement for sarcomas around the knee. Clin Orthop 1992;275:226–231.
19. Jaureguito JW, Dubois CM, Smith SR, et al.: Medial gastrocnemius transposition flap for the treatment of disruption of the extensor mechanism after total knee arthroplasty. J Bone Joint Surg [Am] 1997;79A:866–873.
20. Otis JC, Burstein AH, Lane JM, et al.: The HSS modular linked system for segmental replacement. In Yamamuro T (ed): ''New Developments for Limb Salvage in Musculoskeletal Tumors.'' Tokyo: Springer Verlag, 1989: 233–236.
21. Finn HA, Golden D, Kneisl JA, et al.: The Finn Knee: Rotating hinge replacement of the knee—preliminary report of new design. In Brown KLB (ed): ''Complications of Limb Salvage, Prevention, Management and Outcome.'' Montreal: ISOLS, 1991: 413–416.
22. Kaplan EL, Meier P: Nonparametric estimation from incomplete observations. J Am Stat Assoc 1958;53:457–481.
23. Cox D: Regression models and life-tables. J Royal Stat Soc Ser B 1972;34:187–220.
24. Simon MA, Aschliman MA, Thomas N, et al.: Limb-salvage treatment versus amputation for osteosarcoma of the distal end of the femur. J Bone Joint Surg [Am] 1986;68A:1331–1337.

25. Winkler K, Beron G, Kotz R, et al.: Neoadjuvant chemotherapy for osteogenic sarcoma: Results of a cooperative German/Austrian study. J Clin Oncol 1984;2:617–624.
26. Link MP, Goorin AM, Miser AW, et al.: The effect of adjuvant chemotherapy on relapse-free survival in patients with osteosarcoma of the extremity. N Engl J Med 1986;314:1600–1606.
27. McDonald DJ, Capanna R, Gherlinzoni F, et al.: Influence of chemotherapy on perioperative complications in limb salvage surgery for bone tumors. Cancer 1990;65:1509–1516.
28. Unwin PS, Cannon SR, Grimer RJ, et al.: Aseptic loosening in cemented custom-made prosthetic replacements for bone tumours of the lower limb. J Bone Joint Surg [Br] 1996;78B:5–13.
29. Choong PFM, Sim FH, Pritchard DJ, et al.: Megaprostheses after resection of distal femoral tumors. Acta Orthop Scand 1996;67: 345–351.
30. Van Krieken FM, Den Heeten GJ, Pedersen DR, et al.: Prediction of muscle and joint loads after segmental femur replacement for osteosarcoma. Clin Orthop 1985;198:273–283.